X-RAY TRANSIENT AGN AND GALAXIES, AND WHY WE NEED NEW SOFT X-RAY SURVEYS

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Abstract

X-ray transience is the most extreme form of variability observed in AGN or normal non-active galaxies. While factors of 2-3 on timescales of days to years are quite common among AGN, X-ray transients appear only once and vanish from the X-ray sky years later. The ROSAT All-Sky Survey with its sensitivity to energies down to 0.1 keV was the an ideal tool to discover these sources. X-ray transience in AGN or galaxies can be caused by dramatic changes in the accretion rate of the central black hole or by changes of the properties of the accretion disk. So far only a handful of sources are known. In order to estimate how often such an event occurs in a galaxy, a new soft X-ray survey is needed. In these proceedings I describe the currently known X-ray transient AGN and galaxies and will argue for a new soft X-ray survey in order to discover more of these extreme X-ray sources.

Key words: X-ray surveys, AGN, X-ray transients

1. Introduction

The ROSAT All-Sky Survey (RASS, Voges et al. 1999) has established a new phenomenon among AGN and galaxies - X-ray transience. These X-ray transient AGN and galaxies are very bright once and appear to be fainter or even vanish in X-rays when observed years later(e.g. Grupe et al. 2001a, Komossa & Bade 1999). X-ray transience can appear in Active Galactic Nuclei as well as in normal non-active galaxies. While the X-ray transience in AGN might be caused by changes of the accretion disk properties, in non-active galaxies it might be caused by an X-ray outburst. These X-ray outbursts can be caused by an accretion event, either by instabilities in the accretion disk or by the disruption of a star by the central black hole. Disk instabilities may cause an X-ray outburst in AGN while the tidal disruption model is favoured to explain the outbursts in non-active galaxies which do not show any signs of nuclear activity.

So far only in one source a response in the optical emission lines has been observed, IC 3599. Future soft X-ray surveys will allow us to search for this type of sources. Fast follow-up observations in the optical and in X-rays will provide us with a powerful tool to map the inner region of an AGN in order to locate the line emitting regions and to describe what the geometry of the whole system is.

2. The Sample

Our sample of soft X-ray AGN contains 113 sources selected from the RASS by the PSPC count rates CR > 0.5 cts s^{-1} and the hardness ratio HR <0.0 (Grupe et al. 1998, Grupe et al. 2001a, Thomas et al. 1999). Pointed PSPC and HRI observations are available for 60 and 50 sources, respectively. All in all, for more than 80 sources at least one pointed observation is available (Grupe et al. 2001a). In this way we have a tool to search for long-term large amplitude variations. Fig. 1 displays the RASS vs. pointed observation count rates. HRI count rates have been converted into PSPC count rates assuming no spectral change between both observations. The solid line marks no change, the short-dashed line a change by a factor of 10 and the long-dashed line by a factor of 100 between the RASS and the pointed observation. Four sources turned out to vary by factors of almost 100 or even more: **IC 3599, WPVS007, RX J1624.9+7554**, and **RX J2217.9–5941**. The first three are X-ray transients while RX J2217.9–5941 is an X-ray transient candidate.

3. X-ray transient AGN and galaxies

3.1. WPVS007

The Narrow-line Seyfert 1 galaxy (NLS1) WPVS 007 was *the* softest AGN observed during the RASS (Grupe et al. 1995b) and had a mean count rate of about 1 cts s^{-1}. In later pointings the source shows only the flux expected from a normal non-active galaxy (Grupe et al. 2001a). The flux measured during the RASS observation was what was expected from an average f_X/f_{opt} ratio of an AGN. The question that has to be asked for WPVS 007 is not why it was bright during the RASS it is more why it is off now and what caused the dramatic switch off of this source in less than three years. A possible scenario to explain this dramatic turn-off is a temperature change in the Comptonization layer of the accretion disk that shifts the soft X-ray photons out of the ROSAT energy window. Because no optical variability has been detected in this source, it can be expected that the AGN engine is still running and

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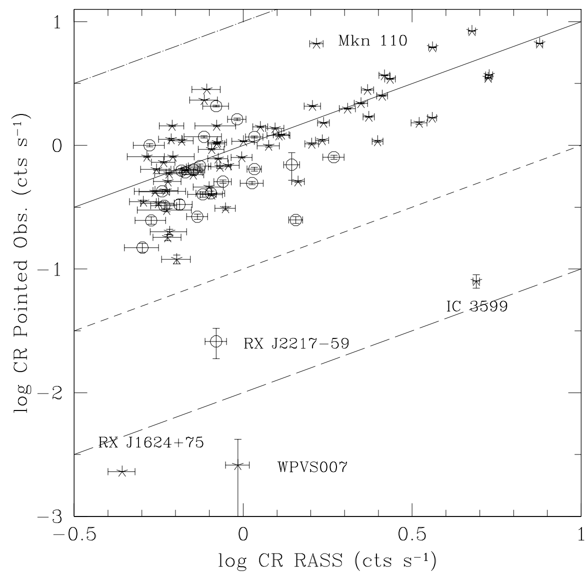

Figure 1. RASS vs. pointed observation count rates (taken from Grupe et al. 2001a)

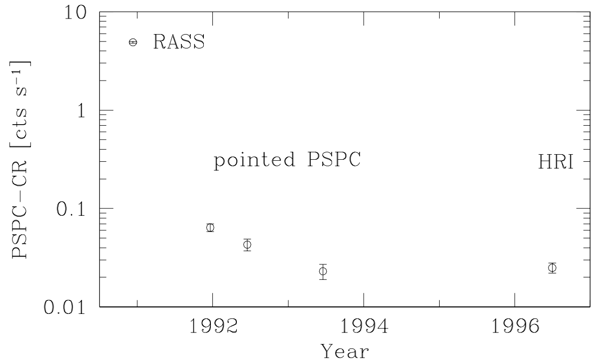

Figure 2. Long-term lightcurve of IC 3599 (taken from Grupe et al. 2001a)

the source should appear in the X-ray sky again. Therefore a monitoring of this source by XMM or Chandra is needed.

3.2. IC 3599

The Seyfert 2 galaxy IC 3599 has shown an X-ray outburst during the RASS (see Fig. 2). During the RASS observation it was one of the brightest AGN in the X-ray sky (4.90 PSPC cts s^{-1}) and has been even seen in ROSAT's Wide Field Camera (Pounds et al. 1993; Edelson et al. 1999). In later pointed PSPC and HRI observations the source showed a dramatic decrease in its count rate over the years (Grupe et al. 2001a). The X-ray outburst during the RASS was followed by a response in its optical emission lines. While in the May 1991 spectrum (Fig. 3; Brandt et al. 1995) the Hβ line as well as highly ionized Fe line (e.g. [FeX]) appear to be extremely strong, in the spectra taken years later (Fig. 3; Grupe et al. 1995a) these lines have become much weaker, but other lines (e.g. FeVII) showed up instead. A possible explanation of this X-ray outburst is an accretion event either caused by an instability of the accretion disk or by a tidal disruption of a star orbiting around the central black hole. Such tidal disruption events have been proposed by e.g. Rees 1990. They are a consequence if every galaxy habours a supermassive black hole in its center (see Rees 1989).

3.3. RX J1624.9+7554

RX J1624.9+7554 has shown a dramatic decrease of its X-ray flux by at least a factor of more than 200 between the RASS and a pointed observation 1.5 years later (Grupe et al. 1999). Optical spectroscopy performed 8 years after the RASS, identified this source as a normal non-active galaxy. Because of the lack of any signs of nuclear activity in this galaxy, the most plausible explanation for this X-ray event is the tidal disruption of a star by the central black hole. With a 0.2-2.0 keV luminosity $L_{\rm X}$=1.6 10^{37} W during the outburst it was the brightest non-active transient observed so far.

3.4. RX J2217.9–5941

The NLS1 RX J2217.9–5941 is a possible X-ray transient candidate. It is highly variable on time scales of days as well as years (Grupe et al. 2001a). During its two-day RASS observation the count rate decrease by a factor of 15. Observed several times in pointed observations by ROSAT and ASCA the source has become fainter over the years. It is not clear yet if this source will become a transient. However, due to the black hole mass of $\approx 10^8 M_\odot$the timescales are larger than in e.g. IC 3599 (M$_{BH}$ $\approx 10^6 M_\odot$). RX J2217.9–5941 might be a bigger brother of WPVS007 and we observe RX J2217.9–5941 slowly become fainter over the years. They both have in common to be NLS1s and have steep X-ray spectra at least during their RASS observation.

3.5. Other X-ray transient galaxies

Besides RX J1624.9+7554 a few more non-active galaxies have been reported of in the literature: NGC 5905, RX J1242.6–1119, and RX J1420.4+5334 (Komossa & Bade 1999; Komossa & Greiner 1999; Greiner et al. 2000). While NGC 5905 was observed in an outburst state during the RASS and a later turn-off, the two other sources are the only examples of a 'turn-on'. Both where brighter when observed in pointed observations after the RASS. All the three sources have in common not to show any signs of nuclear activity. The most plausible explanation for the

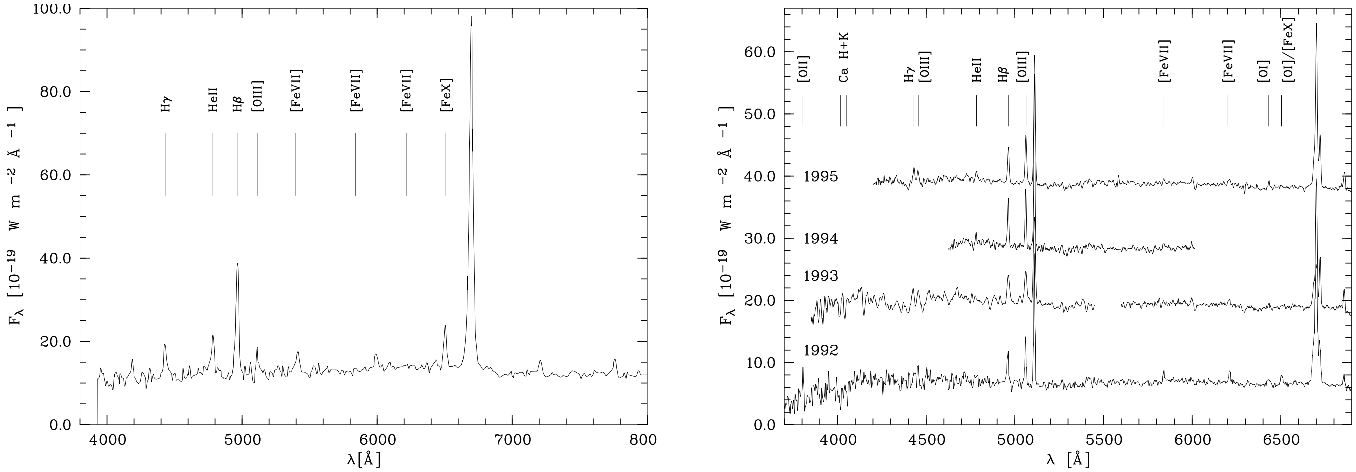

Figure 3. Optical spectra of IC 3599. The left panel displays the spectrum taken half a year after the X-ray outburst during the RASS (taken from Brandt et al. 1995) and the right panel shows the spectra taken years later (Grupe et al. 1995a). The spectra of 1993, 1994, and 1995 are displayed with an offset.

outburst is like in RX J1624.9+7554 a tidal disruption of a star by the central black hole.

4. Discussion

The ROSAT All-Sky Survey has shown the potential of soft X-ray surveys to discover X-ray transient AGN and galaxies. There are in principle two types of transience in AGN and galaxies: a) a sudden decrease of the X-ray flux in normally bright X-ray sources, and b) an X-ray outburst caused by either an accretion disk instability or by a tidal disruption of a star orbiting the central black hole. The first case, which might have been seen in WPVS 007 and RX J2217.9–5941, might be the transition between a high into a low state. Such behaviour is known from galactic black hole candidates. The second case, an X-ray outburst, was observed in IC 3599, NGC 5905, RX J1624.9+7554, RX J1242.6–1119, and RX J1420.4+5334. The follow-up optical observations of IC 3599 showed how the light front moved through the inner region of the AGN/galaxy and caused different emission lines to show up over time. While reverberation mapping is a powerful tool in bright, 'normal' AGN to map the inner region, X-ray transient AGN and galaxies show much larger and dramatic changes in their optical spectra. The only problem is, such X-ray outburst events are rare. In order to find those extraordinary sources, soft X-ray surveys are needed.

New soft X-ray surveys will provide us with a statistically relevant data set that can clarify how common the chance between low and high states is in AGN. Repeating soft X-ray surveys will also give us an estimate how often outburst events appear in non-active galaxies, or in other words, how many years we have to wait until such an event happens in a galaxy. This result is also of interest for our own galaxy, which black hole mass of 2.6 $10^6 M_\odot$is comparable to the ones found in the galaxies in which an outburst occurred.

The requirements for future soft X-ray surveys are being sensitive at energies <0.3 keV and using an imaging X-ray telescope with a high effective area and a large field of view. A sensitivity in soft X-rays (<0.3 keV, at least) is needed, because X-ray outbursts have a very soft X-ray spectrum, due to the high accretion rate during the event. A high effective area is needed for getting enough photons to derive spectra and lightcurves on short timescales. And last but not least, a large field of view is needed to get a long coverage of the source when passing through the field of view of the telescope.

Currently, three X-ray surveys are planned, ROSITA, Lobster Eye, and MAXI. They all have in common to work at higher energies. While ROSITA may have enough spatial resolution to identify the optical counterpart of an X-ray transient, Lobster Eye is an all-sky monitor which does not have enough spatial resolving power. MAXI will not have enough spatial resolution either, plus will not be sensitive to low energy photons. ROSITA will be a powerful tool to discover obscured hard AGN, but inefficient for the search of short living soft X-ray events such as X-ray outburst. The other problem is that the number of photons collected per scan is too small to derive lightcurves and spectra. Therefore, none of the currently planned X-ray survey missions fullfill the requirements for a search for soft X-ray transient AGN and galaxies. Therefore a new soft X-ray survey mission is needed, performed in a similar way as the RASS was, except it should be repeated several times in order to a) get long-term light curves, b) see the same number of 'turn-ons' as 'turn-offs'. Such a survey will not be only important for AGN/galaxy research, it is also needed for the discovery and study of e.g. new cataclysmic variables and super-soft X-ray sources.

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